Chapter 25

An experimental prototype coral reef tank at the Steinhart Aquarium's temporary museum

BART SHEPHERD

Steinhart Aquarium, California Academy of Sciences,
55 Music Concourse Drive, San Francisco CA 94118, USA
bshepherd@calacademy.org

ABSTRACT

In 2004, the Steinhart Aquarium moved out of its historic building in Golden Gate Park into a temporary museum in downtown San Francisco. This transition site is our home for four years while our permanent facility is completely reconstructed. For the aquarium staff, this is a time of intense planning and prototyping. We are also enhancing our living collection, starting from a foundation of specimens transported from the old location. In order to maintain the large collection of reef organisms housed in our previous facility, as well as to plan and prepare for the future, we constructed a 5.5 m deep, 75.7 m^3 coral reef aquarium. This "experimental prototype" is roughly one tenth the volume of the exhibit we are developing for our new facility, is similar in depth, and has a life support system based upon the configuration of our future display. This paper describes the prototype tank and its life support systems and will also detail the methods used to manage the filtration system in order to optimize water quality with minimal water exchanges. The lessons learned during the transition period and how they helped shape the design of the future tank are also outlined.

INTRODUCTION

The Steinhart Aquarium, founded in 1923, is one of the oldest municipal aquariums in the United States. For 81 years, the Steinhart Aquarium inspired, educated and entertained its guests by portraying a wide diversity of aquatic organisms and habitats in a Victorian-style building in San Francisco's famous Golden Gate Park. Years of saltwater corrosion, damage from the 1989 Loma Prieta earthquake and changing tastes and technologies necessitated that this facility be completely rebuilt. In early 2004, the gems of the Steinhart living collection, including a diverse group of coral reef fishes and invertebrates, were moved to a temporary museum, constructed in an office building in downtown San Francisco.

The centerpiece of this temporary home is a large, 5.5 m deep, 75.7 m^3 coral reef aquarium. The three primary goals behind establishing such a large scale, yet impermanent reef aquarium were to create a spectacular centerpiece exhibit for the museum, to maintain the already-present, wonderfully diverse and valuable collection of reef organisms, and to evaluate and influence the designs for the next generation Steinhart Aquarium, part of the brand-new California Academy of Sciences, set to open in Golden Gate Park in late 2008. Of particular importance, this last goal was to increase staff experience with large life support systems by prototyping those planned for the new Steinhart exhibits, as well as investigate methods for providing suitable light levels in deep tanks ($\geq$3 m). This paper will focus on the design of the Howard Street tank, and management of the life support systems. The testing and development of effective lighting systems for deep tanks will be summarized in an additional paper in these proceedings.

AN EXPERIMENTAL PROTOTYPE REEF AQUARIUM

This reef aquarium differs from most of our sister institutions' by several aspects. First, there is

the temporary nature. The 5.5 m cube-shaped, concrete tank was constructed in early 2004 and will be completely demolished by February 2009, when the leased building will be returned to the landlord. Second, there are the aesthetic goals. Because the primary concerns were to provide temporary housing for reef corals and fish and to experiment with new techniques and technology, the exhibit is not naturalistic in appearance. The concrete walls and floor of this tank were left bare and uncovered. This is one area where the prototype varies from the final exhibit. This was largely the result of the geometry of the tank (tall and narrow, with limited surface area at the bottom) and the layout of the mechanical equipment (all life support system inlets and outlets located in close proximity to the bottom). Instead of a sand substratum or reef structure, there are seven shelves constructed of fiberglass grating and strut, which support all of the live rock and living corals. No attempt was made to camouflage the shelving or the in-tank plumbing. The analogy pursued was of a "staging area", similar to the methods used to display and maintain a collection of bonsai plants. This supports one of the major themes of the temporary museum, "the aquarium uncovered": presenting guests with opportunities to look behind the scenes and see what is necessary to maintain a public aquarium facility.

The visual impact of the coral reef exhibit was important, so several distinct viewing locations were provided for our guests. The main viewing panel is a 4 m tall, 2.1 m wide piece of acrylic that gives a full view into the front of the tank. The secondary viewing window, located on the stair landing approximately half way up the left side of the tank, is 2.1 m wide and 2 m tall. This window offers our guests an up close and personal view of clownfish and sea anemones, and is one of the most popular sections of the museum. Along the opposite side of the exhibit are three 1.2 m diameter bubble-windows: one looks into the tank, and children use it to immerse themselves in the underwater realm. The two other bubble windows pop out of the tank and create luminescent patterns on the walls and floors in the adjacent gallery.

To increase the appeal and appreciation of this tank, a weekly "Coral Reef Caretaking" public program is also incorporated. During this time (Monday and Wednesday at 2 pm), aquarium biologists interact with guests and offer them a glimpse of what it takes to maintain the exhibit. One biologist greets the guests, tells them about the aquarium, answers questions and feeds the fishes. A second biologist then comes out and SCUBA dives in the tank, cleaning the windows, checking the animals and equipment, and hand-feeding some fishes and all of the sea anemones. This program has been very positively received by the public, and has boosted attendance during the early afternoons, which is usually a quiet time for the facility. It is a model of a type of program we call "people-facilitated-experiences" (PFE) that is being developed and evaluated for use in the new facility.

LIFE SUPPORT SYSTEM DESIGN

The Life Support System (LSS) divides filtration relatively equally between foam fractionation (protein skimming) and mechanical filtration via High Pressure Sand Filters (HPSF). The LSS is summarized in Figure 1 and Appendix I. The main filtration loop consists of a 45-minute turnover through the HPSF, draining from a surface skimming weir box and returning through the bottom of the tank. A side-stream from the sump delivers a 60-minute turnover through the protein skimmers. A separate loop feeds two chillers and a calcium reactor system. Actual turnover times are verified by flow meters and the calculated volume of the system, and mimic the theoretical turnovers planned for the final exhibit by our life-support engineers.

Two OZ2RTUSL-V/PM ozone generators (Ozone Water Systems, Sunnyvale CA, USA) inject ozone into the fractionators. Ozone is used sparingly and cautiously in order to improve water clarity and enhance the breakdown and removal of organics by the foam fractionators. Digital redox-potential (ORP) meters integrated within the ozone system monitor dosing rates and control a safety mechanism to help prevent overdosing. Aquarium biologists manually turn the ozone system on first thing in the morning and off at the end of the workday, timing ozone administration to coincide with the nutrient input that occurs during and after heavy feedings (Krumins *et al.*, 2001). ORP is typically maintained between 225 and 300 mV using this method.

A flexible, adjustable circulation system was designed in order to create the water movement necessary to successfully grow reef-building corals. This was especially important due to
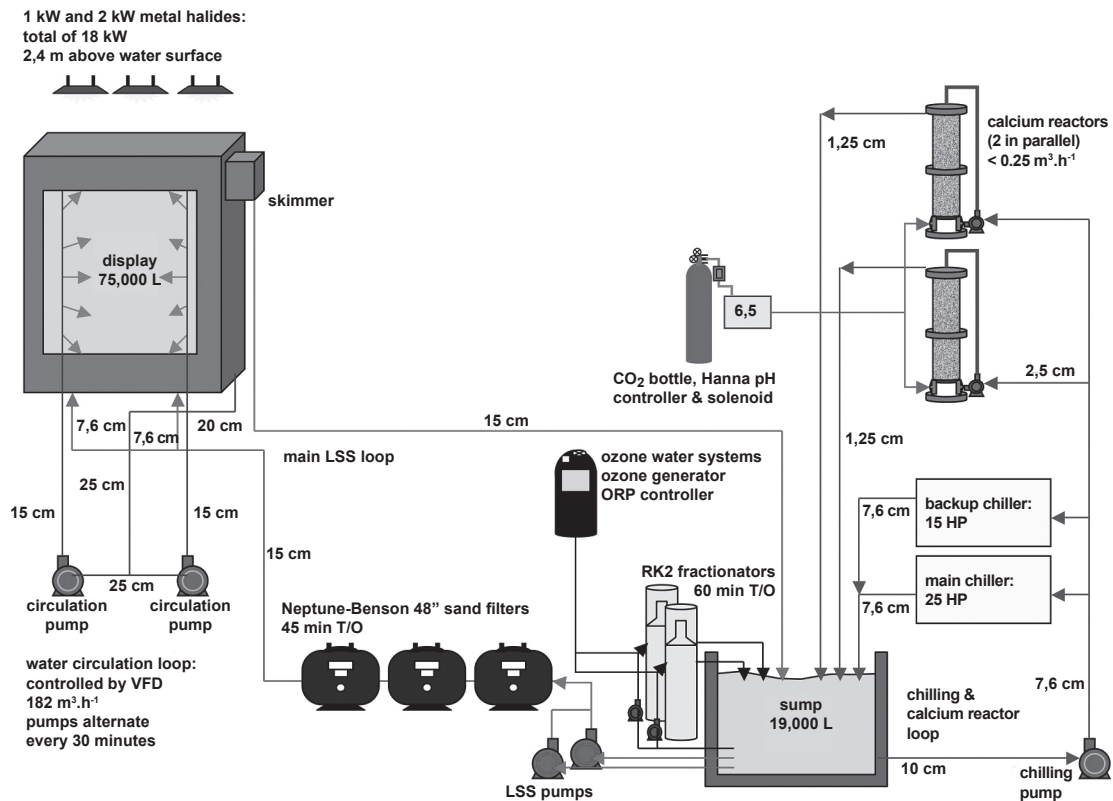
Figure 1: Schematic design of the life support systems for our temporary coral reef aquarium showing the various plumbing loops and all of the major components. Pipe diameters and flow rates are indicated for the various plumbing runs

the geometry of the exhibit (tall and narrow, with short distances between the circulation nozzles and the living corals). In order to create changing flow regimes, two 25 HP pumps were coupled with variable frequency drivers (VFD) that control the pump motors by regulating flow rates (Pumpsmart PS200, ITT Industries, Seneca Falls, NY, USA). Each pump feeds a vertical manifold of 16 nozzles. Each nozzle is constructed of a pair of 90° angle fittings that are threaded and thus can be redirected as needed. On each manifold, six of these nozzles have eductors to increase water flow and to reduce velocities on nozzles located in close proximity to the corals. A single 25 HP pump drives 193 $m^3.h^{-1}$ through a single vertical manifold at any given time. The two pumps alternate, with approximately one half hour per pump cycle. No attempt has been made to quantify water motion in the exhibit (aside from the flow meters on the pumps) but we know that flow varies widely throughout the exhibit. Water circulation is one area where this tank is deficient. Some areas, such as the uppermost shelf, have low flow, and it is impossible to increase this by adjusting the nozzles. In response to this finding, more robust and flexible circulation systems will be incorporated in the permanent exhibit.

Calcium reactors were constructed in-house and were based upon designs employed at Atlantis Marine World (Yaiullo, pers. com.), Aquarium of the Pacific (Clarkson, pers. com.), and Colorado Ocean Journey (now Landry's Downtown Aquarium) (Brynda, pers. com.). We modified these designs to increase the media capacity and to facilitate disassembly for maintenance (Figure 2). Our reactors have bolt-together flanges on the top, bottom and in the middle of the chambers, allowing for partial or complete disassembly for refilling and maintenance. There is also a series of valves that allow the reactors to be backwashed, which facilitates maintenance and replenishing the media. The reactors were sized based upon two methods of estimating calcium demand. First, calcification rates of 7-12 $kg.m^{-2}.y^{-1}$ from scientific studies in the field were applied to the surface area of our exhibit (Pichon, 1985; Adey and Loveland, 1998). To confirm these numbers, the capacity of our previous exhibit's system was recalculated (six Knop HD reactors, Knop Aquarientechnik, Pirmasens, Germany)
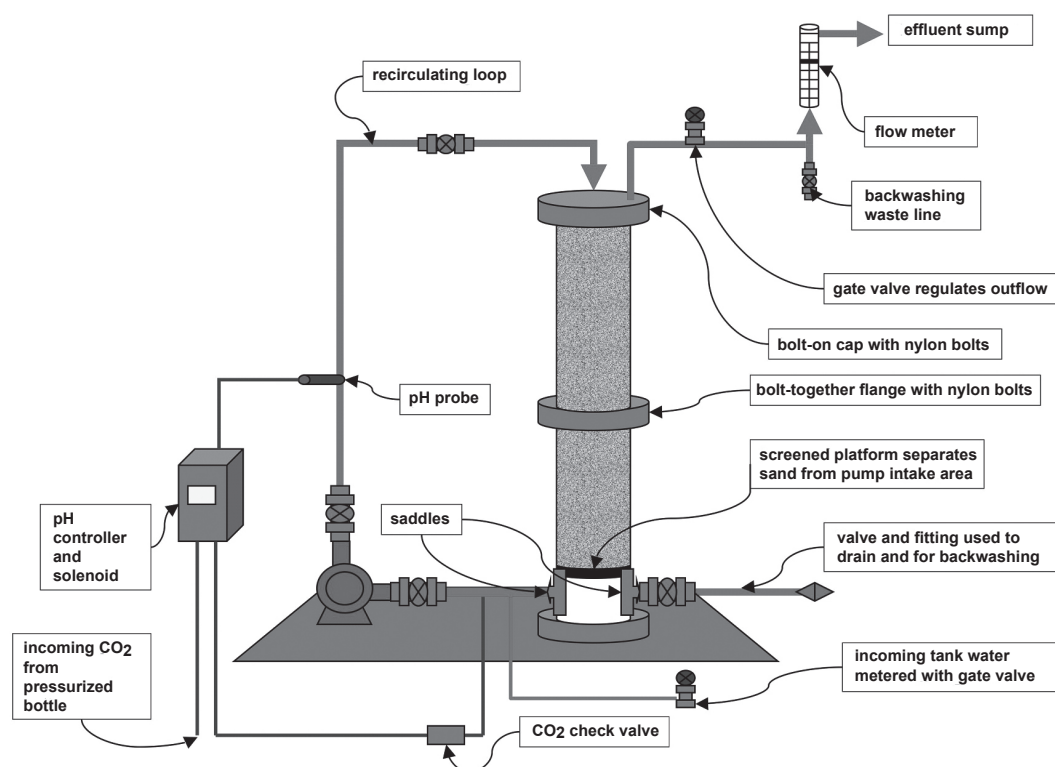
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Figure 2: Schematic design for the calcium reactors utilized on the Steinhart Aquarium experimental coral reef tank

for the volume of the new aquarium. These two calculations produced similar results, and led us to conclude that a pair of 2.4 m tall, 20 cm diameter cylinders would meet the demand of our system. Each of these columns holds approximately 72 kg of coral gravel (CaribSea GeoMarine, 3-5 mm in size), and each dissolves this media in about 6 months. This correlates with a calcification rate of approximately 15 $kg.m^{-2}.y^{-1}$, assuming the tank has a reef surface area of 19 m^2.

Because of the geometry of the exhibit (tall and narrow, with little surface area), there is minimal evaporation. Initially, a calcium hydroxide "kalkwasser" reactor was constructed. It was fed by deionized water, and was intended to compensate for all water lost to evaporation. Rather quickly it was determined that make-up water was unnecessary, and so this system was never used. This was quite surprising due to the thousands of Watts of metal halide lighting mounted only 2.5 m off of the water surface, and the dedicated ventilation ducts removing hot, humid air from the area immediately above the exhibit. Biologists dose the system with approximately 400 g dry calcium hydroxide ($Ca(OH)_2$) every day in order to reap some of the benefits of kalkwasser (high pH, precipitation of phosphate, calcium supplementation,

etc.). Salinity is maintained between 33 and 35 ppt. The minimal water lost during HPSF backwashing is replenished with synthetic seawater (Instant Ocean, Mentor, OH, USA) on a weekly basis. This amounts to a 5 % weekly water exchange.

MANAGEMENT OF HIGH PRESSURE SAND FILTERS

When constructing large-scale, closed-system public aquarium exhibits, a preferred method for maintaining high water clarity is via HPSF. Typically, these filters are used in high-density fish or mammal systems, where there is a large amount of particulate waste to be removed, or on large-volume exhibits with long view paths and big windows. More often than not, coral reef aquaria are constructed without mechanical filtration. The rationale for avoiding mechanical filters on reef aquariums is because water flow is continually forced over the trapped particles, breaking them down and adding nutrients to the water (Delbeek and Sprung, 2005). Unless cleaned regularly, mechanical filters can become biological filters. By harboring bacterial colonies, HPSF produce nitrate. Elevated nitrate concentrations diminish alkalinity, and can lead to problematic algae and poor invertebrate

health (Moe, 1989; Delbeek and Sprung, 1994; Delbeek and Sprung, 2005). While there is certainly some debate surrounding the toxicity of nitrate to corals and what the ideal nitrate concentration for reef aquaria is, many authors recommend maintaining levels below 10-20 mg NO_3^-.L^{-1} for optimum invertebrate health (Spotte, 1973; Moe, 1989; Borneman, 2001). This was our goal.

Proper management of HPSF includes frequent backwashing and stirring of the sand. For these reasons, HPSF are labor-intensive and wasteful in terms of water consumption. These two properties can steer facilities to prolong the period of time between backwashing, leading to additional nitrate production due to the healthy bacterial colonies growing within the sand substrate. Because of the labor involved, many facilities put filter backwashing on a schedule either based upon a diminished percentage of flow rates, or on a regular maintenance interval. Consolidation or channeling of the sand, coupled with infrequent backwashing can lead to nutrient entrapment and poor long-term water quality, especially in systems for

sensitive organisms such as live stony corals. It was found that by adjusting the frequency, duration and source water for backwashes, it was possible to mitigate the production of nitrate by bacterial colonies (Figure 3). In the first four months of maintaining this exhibit, nitrate concentrations hovered around 20-25 mg NO_3^-.L^{-1}. During this time, the three HPSF were backwashed only when flow rates dropped to 75 % of the maximum (79.5 m^3.h^{-1} vs. 102.2 m^3.h^{-1}). Filters were backwashed with San Francisco municipal drinking water (including chloramines: a stable disinfecting agent that is used in some municipalities in the United States) for a period of 4 minutes per filter at a flow rate of approximately 60.0 m^3.h^{-1} . The time between filter backwashes was approximately 3 weeks.

Because nitrate levels were consistently 20-25 mg.L^{-1} , other methods were investigated to decrease the concentration. Initially, backwash frequency was reexamined: decreasing the interval between backwashing from 3 weeks to 2 weeks, and then to 1 week. This provided satisfactory results, but nitrate concentrations
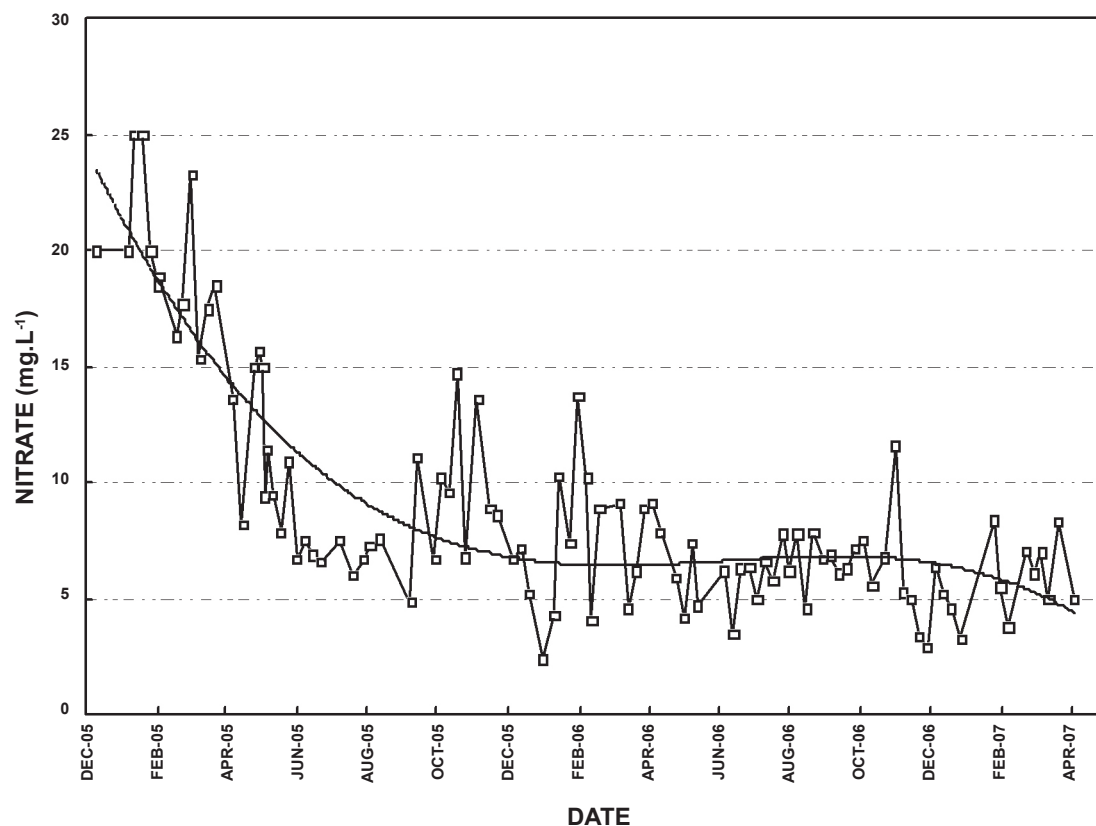

Figure 3: Nitrate concentration has dropped from an initial level of 20-25 mg.L^{-1} to levels hovering around 5-7 mg.L^{-1}. We believe that this is due to our management of the life support systems: in particular, backwashing of high-pressure sand filters. Nitrate is measured weekly as ionic nitrate, NO_3^-, using a Hach DR 890 colorimeter. The trend line shows a third order polynomial regression, which has an R^2 of 0.7188

were still above our goal. It was not until we also increased the duration of backwashing from 4 minutes at 60.0 $m^3.h^{-1}$ to 10-12 minutes per filter at 60.0 $m^3.h^{-1}$ that nitrate concentrations were consistently below 10 $mg.L^{-1}$ (Delbeek, pers. com.). A resting period was also incorporated, where the sand filters sit full of chloraminated freshwater while the neighboring filters are backwashed.

As the population of fishes rose from 75 to well over 400, nitrate concentrations have continued to trend up, most likely due to increased food input. In response, the backwash duration was increased to 15 minutes per filter. Using this methodology, nitrate concentrations from 10-15 $mg.L^{-1}$ have been maintained for over 2 years, proving that, if managed properly, intensive use of HPSF does not automatically lead to high nitrates.

LIGHTING

The lighting for this system was, by far, the most experimental aspect of the exhibit. It has been a long process, conducted with the input and experience of electricians, lighting designers, exhibit designers, biologists, electrical engineers, outside consultants and assorted other "special interest groups". Initially, this system was designed to rely exclusively upon ten Sill 2 kW metal halide fixtures (using Sylvania ballasts) with two reflector angles specified to illuminate both shallow and deep sections of the tank. This setup was effective, and provided PAR levels greater than 500 $\mu E.m^{-2}.s^{-1}$ at depths of 5.5 m (See Delbeek and Sprung, 2005 for a photograph of the system and data). However, within six months of opening this exhibit, the capacitors in the ballast assembly began to combust and drip melted electrical compound out of the enclosure on to the public floor. Our research showed that this was because the manufacturer had not properly matched the ballast to the lamp. As the lamp aged, it became harder for the igniter and capacitor to start the lamp. These repeated "hard-starts" caused the capacitors to fail in a very dramatic and hazardous manner. Because the manufacturer was unresponsive to requests for assistance, both an initial (re-engineering the Sill/Sylvania system to be more reliable) and a permanent solution (identification, evaluation and installation of alternate fixtures) were developed.

Currently the exhibit is lit with a combination of four different fixtures, four ballast systems and six different lamps. Sill systems (now with more dependable European Vossloh/Schwabe ballasts and dedicated transformers) are used alongside GE 2 kW fixtures. The Sill fixtures operate Osram and Ushio lamps, and the GE fixtures use an APL lamp. We also use Sill 1kW fixtures with Osram lamps, and Hubbell 1kW fixtures with Sunmaster and Venture-Blue lamps. The manufacturer information is summarized in Appendix 1 and more specific information about this equipment is given in a second paper in these proceedings. Figure 4 describes the light levels maintained by this revised system at various locations throughout our tank. In contrast to the initial system (described in Delbeek and Sprung, 2005), this revised lighting system creates more uniform light levels within the tank. Interestingly, the theoretical hotspot (center of tank, just under water surface) is no longer the actual hotspot. The highest PAR reading in the tank is under nearly 4 m of water (1850 $\mu E.m^{-2}.s^{-1}$). This is due to the synergistic effects of overlapping beams. Many fixture, ballast and lamp combinations available in the United States were evaluated for PAR, lamp life, color temperature and reliability. The specific results of these tests are summarized in an additional paper in these proceedings.

CLOSING REMARKS

The living collection relocated from the old Steinhart facility provided the backbone for the organisms displayed in this aquarium. There were initially 75 fishes of various species, 1,850 kg of live rock, and several hundred colonies of living coral: mostly octocorals, corallimorpharians and zooanthids. To this collection, numerous species of corals, an additional 450 kg of live rock, as well as nearly 400 fishes have been added (see Appendix 2 for species list). Currently experiments are underway with many species of fish generally not considered "reef safe": e.g. the clown trigger (*Balistoides conspiscillum*), Niger trigger (*Odonus niger*), Emperor Angel (*Pomacanthus imperator*), Harlequin Tuskfish (*Choerodon fasciatus*), various butterflyfishes (*Chaetodon* spp.) and these will continue as we develop the living collection for the new 757 m^3 Philippine Coral Reef exhibit in the Golden Gate Park location.
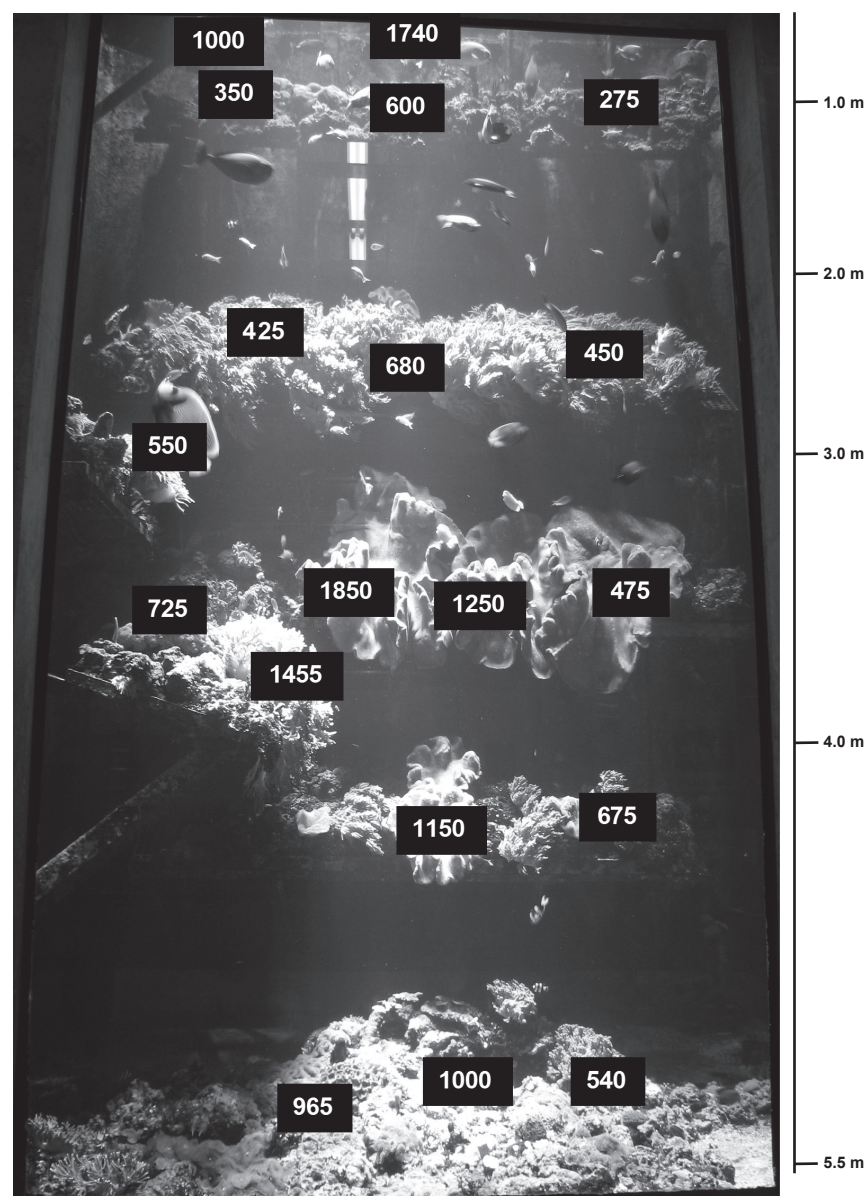
Figure 4: PAR levels (measured as photosynthetic photon flux, $\mu E.m^{-2}.s^{-1}$) recorded using a Li-Cor LI-193SA spherical quantum sensor and Li-1400 datalogger (Li-Cor, Inc. Lincoln Nebraska, USA). Approximate depth indicated by scale bar at right

The Steinhart Aquarium has spent the past several years in a wonderful, albeit temporary home in downtown San Francisco. This time has been a blessing: both in terms of the ability to stay in the public eye during a complete reconstruction, as well as for the opportunity to test, prototype and refine exhibits for the institution's return to Golden Gate Park. The centerpiece of this temporary museum, the large-scale, experimental coral reef tank, has been used to great effect to guide the development of LSS designs, stocking plans, guest-interactive programs and operational procedures that will be employed when the new Steinhart Aquarium reopens in the park in late 2008.

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Langlands and Dean Do, facilitated our research on lighting with patience and a curiosity of their own. The aquarium engineers masterfully manage the life support systems and keep the water in the tank (most of the time), and the aquarium laboratory has kept us honest and on track with regard to water chemistry, quarantine and prophylactic treatments. The Kingfisher Foundation provided significant support for our efforts at sustainable collection building. This paper benefited greatly from comments by two anonymous reviewers and many discussions with fellow public aquarium colleagues and reefkeepers. Finally, I would like to thank the myriad of hobbyists and professional colleagues that have contributed animals of all shapes and sizes for our exhibit development.

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Spotte, S., 1973. Marine Aquarium Keeping: The Science, Animals and Art. John Wiley and Sons, New York. 171 pp.

PERSONAL COMMUNICATIONS

Brynda, R., 2007. Landry's Downtown Aquarium, Denver, CO, 80211, USA.

Clarkson, P., 2007. Aquarium of the Pacific, Long Beach, CA, 90802, USA.

Delbeek, J. C., 2007. Waikiki Aquarium, Honolulu, HI, 96815, USA.

Yaiullo, J., 2007. Atlantis Marine World, Riverhead NY, 11901, USA

APPENDIX I: Aquarium Passport

Tank name   Coral Reef
Location   Steinhart Aquarium, California Academy of Sciences temporary
                                  museum site (875 Howard Street, San Francisco, CA 94103)
Opening date   July 2004 (Tank will be completely dismantled in late 2008)

INFRASTRUCTURE / PHYSICAL DESCRIPTION
Volume   75.7 m^3
Surface area   FRP shelving creating approximately 20 m^2 for coral placement
Depth   6 m. Corals from 0.2 to 6 m

LIGHT CONDITIONS
General   1 kW and 2 kW metal halide fixtures, number and combination has
                                  varied during life of exhibit. At the time of writing, the lighting consists of
                                  18 kW, provided by the following system:

                                  4 x Sill 2 kW fixtures (Vossloh/Schwabe ballast, Osram 5,900 K lamp)
                                  2 x GE 2 kW fixtures (GE ballast, APL 5,600 K lamp)
                                  2 x Sill 1 kW fixtures (Vossloh/Schwabe ballast, Osram 5,600 K lamp)
                                  2 x Hubbell 1 kW fixtures (M47 ballast, Sunmaster 6,500 K lamp)
                                  2 x Hubbell 1 kW fixtures (M47 ballast, Venture-blue 20,000 K lamp)

                                  Franz Sill GmbH, Berlin, Germany
                                General Electric, Fairfield Connecticut, USA
                                Hubbell Lighting, Greenville, South Carolina, USA
                                Osram GmbH, Munich, Germany
                                  Sunmaster, Salon, Ohio, USA
                                  Venture Lighting International, Salon, Ohio, USA
Hours of illumination Thirteen hours (8 am to 9 pm) with one hour dawn (8-9 am) and dusk
                                  (8-9 pm) periods with only 2 x 1 kW Venture Blue lamps
Daily max PAR   Varies extensively throughout the exhibit from 200-2,000 $\mu E.m^{-2}.s^{-1}$

FILTRATION (external)
Protein skimmers   2 x RK2 PE-150 Foam Fractionators (RK2, Escondido CA, USA)
Ozone injection   2 x OZ2RTUSL-V/PM ozone generators (Ozone Water Systems,
                                  Sunnyvale CA, USA), with ORP controllers and oxygen generators.
                                  Ozone is controlled manually and used from 8 am to 5 pm daily
Sand filters   3 x Neptune-Benson 48 CCFG-3 (Neptune-Benson Inc., Coventry RI,
                                  USA) 1.2 m diameter high-pressure sand filters

FILTRATION (internal)
Live-rocks   2.26 metric tons of live rock: 80 % collected, 20 % cultured (Walt Smith
                                  International, Fiji)
Substrate   No sand substrate present

WATER MOVEMENT / CIRCULATION
External pumps   2 x 25 HP circulation pumps produce 180 $m^3.h^{-1}$ each
Total flow   Circulation system provides 180 $m^3.h^{-1}$. Direction alternates every 0.5
                                  hour, controlled by digital VFD controllers (Pumpsmart PS200, ITT
                                  Industries, Seneca Falls, NY, USA)
                                  Filtration system provides 96 $m^3.h^{-1}$ through HPSF
Turn over rates   45 min. through HPSF
                                  60 min. through protein skimmers

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APPENDIX I (continued): Aquarium Passport

WATER CHANGES

Source of "new"
salt-water   Dechloraminated San Francisco municipal water mixed with Instant
                        Ocean (Mentor, Ohio, USA) synthetic sea salts to 32-35 ppt

Rate of water
replacement   Approximately 5 % per week to makeup for water lost in filter backwash

FEEDING REGIME

Dead food   Various commercial dried and frozen foods, along with a homemade
                        gelatin diet for herbivores. Tank is fed 2-3 x.d^{-1}
Live food   Enriched *Artemia* adults and nauplii

WATER QUALITY

Salinity   33 to 35 ppt
Temperature   25-26 °C
pH   8.1 to 8.3
Calcium (Ca^{2+})   400 to 450 mg .L^{-1}
Alkalinity   2.5 to 4.6 mEq.L^{-1}
Redox (mV)   225 to 300 mV
Nutrients   Nitrate (NO$_3^-$-N):   5 to 15 mg.L^{-1}
                        Phosphate (PO$_4^{3-}$-P):   0.01 to 0.15 mg.L^{-1}

CHEMICAL ADDITIONS

Calcium   Approximately 400 g dry calcium hydroxide (Ca(OH)$_2$) per day added to
                        sump
Alkalinity   Custom built calcium carbonate reactor system dissolves approximately
                        24 kg per month of aragonite gravel
Trace elements   No additions made

APPENDIX II: Aquarium Inhabitants

Genus	Species	Common names	#
FISH			
Acanthurus	achilles	Achilles Surgeonfish	2
Acanthurus	dussumieri	Eye-stripe Surgeonfish	2
Acanthurus	japonicus	Japanese Surgeonfish	20
Acanthurus	leucosternon	Powder blue Surgeonfish	1
Acanthurus	lineatus	Lined Surgeonfish	4
Acanthurus	mata	Mata Surgeonfish	2
Acanthurus	olivaceus	Orange-Spot Surgeonfish	2
Acanthurus	pyroferus	Mimic Surgeonfish	40
Acanthurus	sohal	Sohal's Surgeonfish	1
Acanthurus	triostegus	Convict Surgeonfish	1
Amphiprion	clarkii	Clark's Anemonefish	2
Amphiprion	ocellaris	Common Clownfish	8
Balistoides	conspicillum	Clown Triggerfish	1
Caesio	teres	Fusilier	75
Calloplesiops	altivelis	Comet	1
Chaetodon	kleinii	Klein's Butterflyfish	1
Chaetodon	miliaris	Lemon Butterflyfish	1
Chelmon	rostratus	Copperband Butterflyfish	1
Choerodon	fasciatus	Harlequin Tuskfish	2
Chromis	viridis	Green Chromis	76
Cirrhilabrus	exquisitus	Exquisite Fairy Wrasse	6
Cirrhilabrus	flavidorsalis	Yellowfin Fairy Wrasse	8
Cirrhilabrus	rubripinnis	Redfin Fairy Wrasse	1
Cirrhilabrus	solorensis	Fairy Wrasse	10
Ctenochaetus	tominiensis	Yellow-Tip Bristletooth	40
Dascillus	melanurus	Humbug	22
Genicanthus	lamarck	Lamarck's Angelfish	15
Genicanthus	melanospilos	Swallowtail Angelfish	3
Halichoeres	chloropterus	Green Wrasse	1
Halichoeres	chrysus	Canary Wrasse	2
Labroides	dimidiatus	Cleaner Wrasse	3
Myripristis	sp.	Soldierfish	2
Naso	brevirostris	Spotted Unicornfish	2
Naso	caeruleacauda	Blue Unicornfish	2
Naso	lituratus	Orangespine Unicornfish	2
Naso	unicornis	Bluespine Unicornfish	1
Naso	vlamingii	Bignose Unicornfish	2
Odonus	niger	Redtooth Triggerfish	2
Paracanthurus	hepatus	Palette Surgeonfish	4
Pomacanthus	imperator	Emperor Angelfish	1
Premnas	biaculeatus	Maroon Clownfish	1
Pseudanthias	bicolor	Bicolor Anthias	3
Pseudanthias	pleurotaenia	Squarespot Anthias	6
Pseudanthias	squammipinnis	Lyretail Anthias	75
Pseudocheilinus	hexataenia	6-line Wrasse	15
Ptereleotris	zebra	Zebra Goby	15
Siganus	guttatus	Gold-saddle Rabbitfish	2
Siganus	tetrazonus	Coral Rabbitfish	1
Siganus	vulpinus	Foxface Rabbitfish	2
Sphaeramia	nematoptera	Pajama cardinalfish	3

APPENDIX II (continued): Aquarium Inhabitants

Genus	Species	Common names	#
FISH			
Thalassoma	*lunare*	Lunar Wrasse	1
Zebrasoma	*flavescens*	Yellow Tang	6
Zebrasoma	*scopas*	Brown Tang	25
Zebrasoma	*veliferum*	Sailfin Tang	10
INVERTEBRATES			
(Coral species with especially large populations are noted as >100)			
Acropora	*austera*	Staghorn Coral	10
Acropora	*gemmifera*	Staghorn Coral	1
Acropora	*latistella*	Staghorn Coral	1
Acropora	*millepora*	Staghorn Coral	1
Acropora	*nana*	Staghorn Coral	4
Alcyonium	sp.	Colt Coral	5
Briareum	spp.	Star Polyps	15
Capnella	sp.	Kenya Tree Coral	2
Cladiella	sp.	Colt Coral	10
Clavularia	sp.	Soft Coral	3
Discosoma	spp.	Corallimorph	>100
Echinopora	*lamellosa*	Stony coral	3
Entacmea	*quadricolor*	Bubble tip sea anemone	20
Galaxea	*fascicularis*	Star coral	6
Heteractis	*magnifica*	Magnificent sea anemone	6
Heteractis	*crispa*	Sebae anemone	1
Hydnophora	*rigida*	Stony coral	10
Lobophytum	spp.	Devil's Finger Coral	20
Palythoa	spp.	Zoanthid	>100
Pocillopora	*damicornis*	Stony coral	>100
Porites	*cylindrica*	Stony coral	2
Protopalythoa	spp.	Zoanthid	>100
Physogyra	*lichtensteini*	Pearl bubble coral	1
Rhodactis	spp.	Corallimorph	>100
Ricordea	*yuma*	Corallimorph	>100
Sarcophyton	spp.	Toadstool Leather Coral	12
Sinularia	spp.	Leather Coral	>100
Turbinaria	*peltata*	Stony coral	1
Zoanthus	spp.	Zoanthid	>100